Macro and Micro Level Soil Resource Mapping for Soil Erosion Assessment and Conservation in Shiwalik Region of Himalayas, India

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1. Abstract

Shiwaliks represent most fragile ecosystem of Himalayas threatened by massive soil erosion hazards. Mapping and assessment of erosion prone areas is pre-requisite for planning soil conservation and watershed management programs. Therefore for better understanding of natural resources at various scales is of vital importance and thus the present study was carried out to assess the soil resources, soil erosion and conservation measures at different scales (macro and micro level), using soil resources data. Soil resource data was generated for Balachur tehsil (County) of Nawanshahr district, Punjab, India for macro level (on 1:50,000 scale) and case study for micro level was carried out by using cadastral maps (scale1:4000) in two contiguous villages of the study area. Satellite images IRS-LISS-III were interpreted for generation of soil resource data. Soil information available for different sources was also supplemented. Various thematic maps *viz.*, physiography, slope, soil, land use, drainage, ground water status and erosion status were generated and integrated in GIS environment. Twelve soil series were identified representing different physiographic units. Topography, drainage pattern and inherent characteristics of soils found to be responsible for major problems such as denudation of Shiwaliks, torrents seasonal stream (*choes)* lands, severe erosion, coarse texture; low ground water table due to less recharge of water. Soil conservation measures (like mechanical, terrace trenching, vegetative, etc.) were suggested to restore the eroded area on sustainable basis. Results of case study indicated that six soil series into 21 soil mapping units occupying 35.2% area, experienced problem of moderate erosion, 27.0% area affected by severe to very severe erosion. Leveling, contour bunding, field bunding, cultivation of thick canopy crops like green gram, moth bean and green manuring crops; construction of vegetative and masonary check dams in higher slopes; sowing and planting on degraded lands; terracing of lands, contour trenching, gully plugging; landslide control measures like masonary spill, waltings structure, etc. have been recommended to check the erosion losses. Water harvesting techniques should be encouraged. '*Choes*' affected sandy and severely eroded soils (0.66%) occurring on moderate slopes with surface boulders are recommended for plantation of erosion resistant grass species like *Sactharunm spp*. To slow down the dissection of these soils due to overflow of water, cultivation of fodder crops by adopting adequate soil conservation practices has been recommended as preventive measures. Studies further indicated that macro-level soil resource mapping is useful for demarcating the general and potential soils. Whereas, for identifying more specific problems and field-level soil conservation measures micro level mapping is more effective.

Key word: Shiwaliks, Soil resource, soil conservation, soil erosion, macro and macro level conservation

2. Introduction

Natural resources in mountainous terrain are profoundly affected by land degradation due to anthropogenic pressure. Shiwaliks are one of the most important and integral part of Himalayas representing most fragile ecosystem of Himalayan mountainous range threatened by massive soil erosion hazards. On account of various forms of degradation, it has been estimated that the loss of 5.334 million tonnes of top soil occurs annually, which is equivalent to 5.37 to 8.4 million tonnes of plant nutrients (Dharuvanarayana and Ram babu, 1983). In some cases the soil loss in Shiwaliks due to erosion up to 400 t ha^{-1} yr^{-1} has been reported (Sidhu *et al.* 2007). Soil erosion is being accelerated in this region due to intensive deforestation, terrace farming on steep slopes, and mining, etc. (Sidhu *et al.* 2000). To minimize land degradation due to soil erosion, numbers of measures are being taken by various agencies. Mapping and assessment of erosion prone areas is pre-requisite for planning soil conservation and watershed management programs. Field size, land use, vegetation, soil, slope, and geomorphology affect the severity of soil erosion losses. Some case studies were also attempted to assess the soil erosion losses and various soil conservation measures to check the erosion on watershed level under watershed development programmes. The macro level planning overlook the farm level planning for soil conservation programmes. The farm continues to be the primary unit of decision making at village level and every action planned is indeed implemented at micro level. Producers generally make decisions to full fill his daily needs and to improve financial conditions. Technicians are also used to rationalize and plan actions for a

specific item or for the production system of the farm. Therefore, the approach of planning and execution of actions at micro level requires changes in relation to how to reflect, rationalize and make decisions, on part of producers and technicians (Wambeke, Jan Van, 2007). Hence for better understanding of natural resources at various scales is of vital importance and thus the present study was carried out to assess the soil resources, soil erosion status and conservation measures at different scales (macro and micro level), using soil resources data.

3. Materials and Methods

The present study belongs to lower Shiwaliks Region of Himalayas. It comprises Balachur tahsil of Nawanshahar district of Punjab, India. The area lies between 31^0-00' to 32^0-05′ N latitude and 75^0-30′ to 76^0-32′ E longitude and covers an area of 50960 ha. The river Sutluj flowing in the southern side whereas entire eastern boundary passes along the Shiwalik range. Geology of the area constitutes of Shiwalik deposits which are composed principally of upper tertiary river deposits or alluvial detritus from sub-aerial wastes of mountain swept and their deposits (Wadia, 1975). Natural vegetation of the Shiwaliks is constituted by northern tropical dry deciduous forest and Himalayan subtropical forest species. Climatically, the area is semiarid subtropical and experience extreme summer and winter seasons. The mean annual temperature is 22.2 ^{0}C. and means annual rainfall is 732.7 mm. About 11% area is occupied by forest, 67% area is under cultivation, 8.9% area is waste land, 3.4% area is unculturable lands and rest of the area is under miscellaneous use.

At macro level, Satellite imageries of #IRS P6 LISS-III were interpreted for physiography, slope, land use, and a slope map of the area was generated (on 50,000 scale) by using remote sensing data and survey of India toposheets (Fig. 1). The collateral data-base containing dug well density, socio-economic data, *etc.* for area have been extracted from the resources data base (Directorate of Economics & Statistics, 2004-05). Soil resource data generated by interpreting the remote sensing data and through reconnaissance and detailed surveys were used in the study area on 1:50,000 scale (Sarma *et al*.1987). Soil profiles representing physiographic units in the area were studied and analyzed for morphological and physico-chemical properties (IARI, 1976). Based on the data the soils were classified and mapped into 12 soil family associations as per criteria outlined in Soil Survey Staff (2006). The soil resource map (on 1:50,000 scale) of Balachur tahsil has been prepared (Fig. 3).The generated data for resources were integrated in GIS environment and thematic information on various themes as slope, soil, land use/land cover, physiography, drainage, etc. were generated on the scale of 1:50,000 scale. A case study was carried out by using cadastral map (scale1:4000) in two contiguous villages namely Boothgarh and Jhandupur of the study area for creating detailed (field to field basis) soil resource data and assessment and chalking out strategies to check erosion losses.

4. Results and Discussion

Macro Level Soil Resource Mapping for Soil Conservation

The study area was categorized into seven physiographic units *viz.,* Shiwalik hill top and slopes (eroded), upper piedmont plain, lower piedmont plain, *choe* belt, old alluvial plain, recent flood plain, and active flood plain. (Fig. 2). The descriptive legend comprising different soil characteristics are presented in table 1. The numerous problems encountered in the study area due to topography, drainage pattern and inherent characteristics of soils have been identified as: These are denudation of Shiwaliks, *choes* lands, severe erosion, coarse texture, very deep ground water table (upto 800 feet) and intensified further less recharge of groundwater. Steeply sloping lands put under cultivation after clearing forests denudation of Shiwaliks and severe soil and water erosion. About 22.2% area is under severe erosion, 60.7% area under moderate erosion.; deposition of sand in the plains converting good lands into sandy wastes, meandering nature, untapped rain water for irrigation, industries and power which cause problem of number of seasonal streams (*choes*); lack of irrigation facilities particularly in the area of undulating plains (NBSS&LUP, 1986). The soil problems along with their correction measures are mentioned in table 2. Soil conservation measures (like mechanical, terrace cultivation, vegetative, etc.) were suggested to restore the eroded area on sustainable basis. The soil erosion and its conservative measures have been discussed below:

Shiwalik hills and upper piedmont plain having shallow soils are subjected to severe to moderate erosion and high runoff losses. These areas support thin forest, scrubs and single cropping in patches. These areas require soil conservation measures like gully plugging, natural water channel (*nala*) bunding, continuous contour trenching and construction of check dams. Cultivation across slope, cultivation of monocots, vegetative bunds, contour vegetative hedges and plantation activities are also needed to control soil erosion losses.

In *Choe* belt lands, soils are deep having sever erosion and high erratic runoff loaded with heavy silt and causes narrow dissected gullies. The soil conservation measures required for these areas are field bunding, terracing of lands, contour trenching, gully plugging, leveling of lands and planting *Agava spp*. Vetiva, Bhaber grass *(Eulaliopis binata*), ber (*Zizypus Jujuba*), etc., walting, and construction of masonary check dams.

In lower piedmont and old alluvial plain, where soil is mainly moderately thick and subjected to moderate erosion losses, soil conservation measures like *nala* bunding and construction of percolation tanks are required to reduce soil erosion and increase soil moisture status. At present some areas are under single cropping. Cultivation across slope, land leveling, vegetative bunds, crop rotation and mixed cropping is essential in such areas to reduce soil erosion.

In recent flood and active flood plain, the soils are mostly deep to very deep having slightly to moderately erosion losses due to low to high runoff. Various soil conservation measures e.g. *nala* bunds, underground bunds and mechanical weirs have been suggested mainly to harness surface water and conserve and recharge groundwater. Areas are experiencing high ground water exploitation for cultivation. Adoption of alternate beds and furrows, crop rotation and mixed cropping, drip irrigation are recommended to facilitate irrigation and conserve underground water.

Micro Level Soil Resource Mapping for Soil Conservation – A Case Study

The macro-level study helps to identify the soil problems in general due to scale limitations. Therefore, on the basis of above macro-level study some hot-spot areas within this macro area which need immediate attention, were selected for detailed and more specific micro level study to chalk out the strategy to check the soil erosion loses at field level. Case studies were carried out in two contiguous villages of the study area namely Boothgarh and Jhandupur of Balachur Tehsil in Nawanshahr district, Punjab (India). It lies on 31^0 08' N latitude and $76^0$21' E longitude having an area of 130 ha. The area constitutes a part of upper piedmont plains and lies immediately adjoining the foot hills of lower Shiwalik hills. It composed principally of upper tertiary river deposits or alluvial detritus from the sub-aerial wastes of mountain swept by river and streams deposits at their foot (Wadia,1975). The cropping system is maize-wheat and maize-fodder/gram. The study area, being small in extent may be specially divided into two geomorphic units at micro-level (i) Interfluvial spurs of channels/nala/c*hoes* (ii) Recent deposits of *choes*/sand bars which include rounded pebbles of comparatively larger size. The relief of area is undulating topography on an elevation of 350-4000 m amsl and drained by *Boothgarh Rivulets* and *Jhandupur Rivulets* (*Khad)* which causes considerable loss of soils due to high velocity of water during rainy season. Detailed soil survey was carried out by using cadastral map (scale1:4000). During detailed field to field investigation, 6 soil series mapped into 21 soil mapping units as phases of soil series (Fig. 4). Detailed soil description along with land capability class, irrigability classes are given in table 3. Results indicated that, 35.2% area experienced problem of moderate erosion, 27.0% area affected by severe to very severe erosion.(Fig. 5).

Leveling, contour bunding, field bunding, cultivation of thick canopy crops like green gram, moth bean and green manuring crops were suggested; construction of vegetative and masonary check dams; sowing and planting on degraded lands; terracing of lands, contour trenching, gully plugging; landslide control measures like masonary spill, waltings structure, etc. have been recommended to check the erosion losses. Water harvesting techniques should be encouraged. '*Choes*' affected sandy and severely eroded soils (0.66%) occurring on moderate slopes with surface boulders are recommended for plantation of erosion resistant grass species like *Sactharunm spp*. and *Bhaber* grass *(Eulaliopis binata*), to slow down the dissection of these soils due to overflow of water, cultivation of fodder crops by adopting adequate soil conservation measures has been recommended. Demarcation of grazing lands, protection of hilltops, proper adoption of farming system are also the major step of soil and water conservation losses.

From the above study, it is concluded that problems related to soil and water losses are interrelated for which information of soil resource is required for assessing soil erosion losses through water runoff. Soil erosion is being accelerated in this region due to intensive deforestation, terrace farming on steep slopes, mining, and denudation of Shiwaliks etc. Field size, land use, vegetation, soil, slope, and geomorphology affect the severity of soil erosion losses. The resource analysis at various scales plays a vital role at the time of arriving definite site specific action plan for soil conservation programmes. Fragile ecosystem of Shiwalik region where land degradation and erosion in general is the threatening problem. To check this problem at field level, micro-level information generated through case studies is more important to control the soil erosion classes.

6. References

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Table 1 Description of soils of Balachur, NawanShahr district, Punjab (India)

Soil Unit	Soil series Association symbol	Soil Series Description	Area	
			Sq. km	%
Soils of Shiwalik Hill Tops and slopes (eroded) (10-15% slopes)				
1	(Jagal-Daghan-Kot)	*Jagal:* Moderately deep to deep, yellowish brown to dark brown, sandy loam over bouldery materials (Lithic Haplustepts). *Daghan*: Shallow to moderately deep, yellowish brown and strong brown, loamy sand to sandy loam over bouldery materials (Lithic Ustrorthents) *Kot* : Very deep, dark brown to yellowish brown, sandy loam to loam soils (Udic Haplustepts) Inclusion of highly broken Shiwalik hill upto the extent of 60% as undifferentiated soils	75.77	14.87
Soils of Upper Piedmont Plain (3-5% slopes)				
2	(Jagal-Kot)	*Jagal :* As above in soil unit 1 *Kot* : As above in soil unit 1	7.38	1.45
3	(Jagal-Daghan)	*Jagal* : As above in soil unit 1 *Daghan*: As above in soil unit 1	12.90	2.53
4	(Parkhowal - Mola)	*Parkhowal:* Very deep, strong brown to yellowish brown, sandy loam soils (Udic Haplustepts) *Mola:* Very deep, dark brown to dark yellowish brown, loam to clay loam soils (Udic Haplustepts)	14.69	2.88
Soils of Lower Piedmont Plain (1-3% slopes)				
5	(Barian-Parkhowal)	*Barian*: Very deep, dark yellowish brown to light yellowish brown, loam to sandy loam over loamy sand. (Fluventic Haplustepts) *Parkhowal:* As above in soil unit 4	8.13	1.60
6	(Rampur - Barian - Hazipur)	*Rampur*: very deep, light yellowish brown to yellowish brown, sandy loam with 1-5% pebbles by volume (Fluventic Haplustepts) *Barian:* As above in soil unit 4 *Hazipur*: Very deep, light grey to light yellowish brown sands, with 1-5% pebbles by volume (Typic Ustipsamments)	136.18	26.72
Soils of Old Alluvial Plain (0-1 & 1-3% slopes)				
7	(Mola-Odra)	*Mola* : Very deep, dark brown to dark yellowish brown, loam to clay loam soils (Udic Haplustepts) Odra : Very deep, dark brown to dark yellowish brown clay loam to silty clay loam soils (Udic Haplustepts)	46.91	9.21
Soils of *Choe* Belt (1-3, 3-5% slopes)				
8	(Parkhowal-Rampur)	Parkhowal: As above in soil unit 4 *Rampur:* As above in soil unit 6	46.69	9.16
Soils of Recent Flood Plains (1-3% slopes)				
9	(Ajampur – Kitna)	*Ajampur*: Very deep, dark brown to yellowish brown fine sandy loam to loam calcareous with very fine variable stratified layers (Typic Ustifluvents) *Kitna:* Very deep, dark brown to dark yellowish brown, silt loam to loam calcareous soils with fine stratification (Typic Ustifluvents)	29.61	5.81
10	(Ajampur – Bajroor)	*Ajampur*: As above in soil unit 9 *Bajroor:* Very deep, light yellowish brown to dark yellowish brown sandy loam over sand calcareous soils, fine stratification ((Typic Ustifluvents)	77.34	15.18
11	(Ajampur – Bajroor – Kitna)	*Ajampur*: As above in soil unit 9 *Bajroor:* As above in soil unit 10 *Kitna:* As above in soil unit 9	11.78	2.31
Soils of Active Flood Plain				
12	Undifferentiated Soils	Undifferentiated soils in *choe* and river beds and their surrounding areas	16.41	3.22
		Miscellaneous	25.63	5.06
		Total area	509.6	100

Table 2 Soil unit wise problems and potential and conservation measures for Balachur tehsil

Soil units	Slope (%)	Land apabi-lity	Land Irrig-ability	Soil Problems /potentials	Conservation measures
1	10-15	VIIe	6t	Highly broken Shiwalik hills, severely eroded, slopes restrict continued cultivation	Terraced bunding, check dams, gully plugging, permanent vegetation though forest and grasses
2, 3	10-15	IIIes - IVes	4st	Moderately to strongly sloping lands, susceptible to runoff losses, erosion and are droughtiness	Need intensive soil conservation measures like check dams, permanent vegetation through plantation of growing tree species and grasses besides contour bunding
4	3-5	IIc-IIIs	2t	These soils are good except that they pose problem due to free calcium carbonate and have slight erosion problem	Suggested to grow climatically suitable crops with good management practices; and plantations across the slopes; Soil and water conservation measures field bunding, leveling of land are required; contour bunding in high slopes
5	1-3	IIc-IIIs	2st-3st	These soils are good except that they pose problem due to free calcium carbonate and have slight erosion problem; problem of topography; problem due to extensive percolation losses and reqire frequent irrigations. Leaching losses and loss nutrient retention capacity of nitrogenous fertilizer	Suggested to grow climatically suitable crops with good management practices; and plantations across the slopes
6	1-3	IIIe-IIIs	3st-4st	Very deep coarse loamy soils, susceptible to erosion, and droughtiness	Needs contour bunding to conserve moisture and soil. Green manuring and row cropping of legume across slopes; bench terrcing, row cropping og legumes
7, 9	0-3, 1-3	IIc	1s, 1-2d	Very deep, well to moderately well drained fine loamy soils. Available moisture is enough to grow crops, they are by far the most potential and productive soils of the area	Grow climatically adapted crops with good management practices; their responses to alternate management is expected to be very good
8	1-3	IIIe-IIIs		Very deep coarse loamy soils , susceptible to erosion, droughty	Needs contour bunding to conserve moisture and soil. Green manuring and row cropping of legume across slopes.
10, 11	1-3	IIc-IIIs	1-2s, 2t	These soils are good except that they pose problem due to free calcium carbonate and have slight erosion problem; loss of irrigation water due to percolation and loss of nutrients due to leaching.	Suggested to grow climatically suitable crops with good management practices; and plantations across the slopes
12		VIIw		Undifferentiated soils in the choe and river beds and surrounding areas, subjected to seasonal floods and water stagnation.	Suite for afforestetion; cultivation to grow vegetables;

Subclass level limitations - ‘e’ - limitations for wind and water erosion; ‘w’- drainage difficulties; ‘s’- soil limitations affecting plant growth; ‘c’ – limitations due to climate

Table 3 Soil series description of Boothgarh and Jhandupur Soils,.

Soil series/ soil units	Description of soil	Land capability unit	Land irrigability sub classes	Soil irriga-bility class	Vegetative group	Area (ha)	(% of TGA)
A soils - occurring on very gently to gently sloping piedmont plain (Udic Haplustepts)							
1	A sand, on 0-1% slopes, with slight erosion	IIIs-1	2s	B	B	8.50	6.53
2	A loamy sand, on 1-3 % slopes, with moderate erosion	IIIs-1	2s	B	B	2.50	1.93
3	A sand, on 1-3 % slopes, with moderate erosion	IIIes-1	2st	B	B	17.10	13.15
4	A sand, on 3-5 % slopes, with sever erosion	IVes-2	3st	B	B	15.10	11.62
B soils - occur on v. gently to gently sloping lands of piedmont plains (Typic Haplustepts)							
5	B sand, on 1-3 % slope with slight erosion	IIs1	2t	B	A	2.90	2.23
6	B sand, on 1-3 % slope with erosion	IIs1	2t	B	A	4.50	3.46
7	B sand, on 3-5 % slopes, with severe erosion	IIes-2	3t	B	A	1.30	1.00
C soils - occur on sand deposits near drainage channels/*choes*. (Typic Ustipsamments)							
8	C sand, on 3-5% slopes, with mod. erosion and stoniness	IIIes-1	3s	C	B	4.10	3.16
9	C sand, on 1-5% slopes, with mod. erosion & stoniness	IV es-3	3s	C	B	2.50	1.92
10	C loamy sand, on 3-5% slopes, with mod. to sever erosion	IV es-2	3st	C	B	7.40	5.69
D soils developed over sand dunes (Typic Ustipsamments)							
11	D sand, on 1-5% slopes, with moderate erosion	III es-1	4s	D	B	3.70	2.84
12	D sand, on 3-5% slopes, with severe erosion	IV es-2	4st	D	B	3.10	2.38
13	D sand, on 5-10% slopes, with very severe erosion	IV es-2	4st	D	J	2.50	1.92
E soil occurs on very gently to gently sloping piedmont plains. (Udic Halpustepts)							
14	E sand, on 1-3% slopes, with moderate erosion	II e-1	2t	A	A	8.10	6.23
15	E sand, on 3-5% slopes, with severe erosion	IIes-1	2t	A	A	1.10	0.84
16	E loamy sand, on 1-3% slopes, with moderate erosion	IIIes-2	3st	A	A	1.00	0.82
F soil occurs on nearly level to gently sloping piedmont plains (Typic Haplustepts)							
17	F loamy sand, on 0-1% slopes, with sligth erosion	II e-1	2t	A	A	5.70	4.38
18	F loamy sand, on 1-3% slopes, with slight erosion	II c-1	2t	A	A	1.10	0.84
19	F loamy sand, on 1-3% slopes, with moderately erosion	IIIes-3	3st	B	A	4.70	3.63
20	F loamy sand, on 1-3% slopes, with moderately erosion and stoniness	IIIes-3	3st	B	A	3.30	2.53
21	F loamy sand, on 3-5% slopes, with severe erosion	IIIes-3	3st	B	A	4.70	3.63
					Habitation	15.70	12.07
					Roads, river and others miscellaneous use	12.80	9.84
					Total	130	100

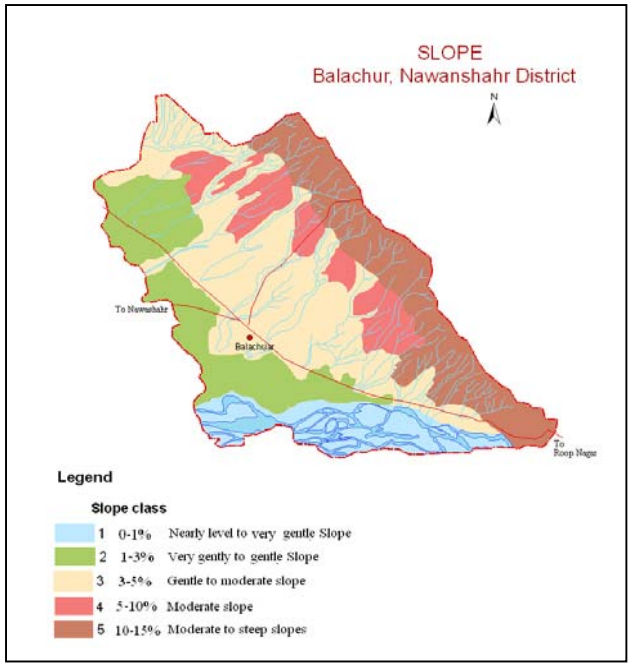

Fig. 1. Slope map of Balachur Tahsil

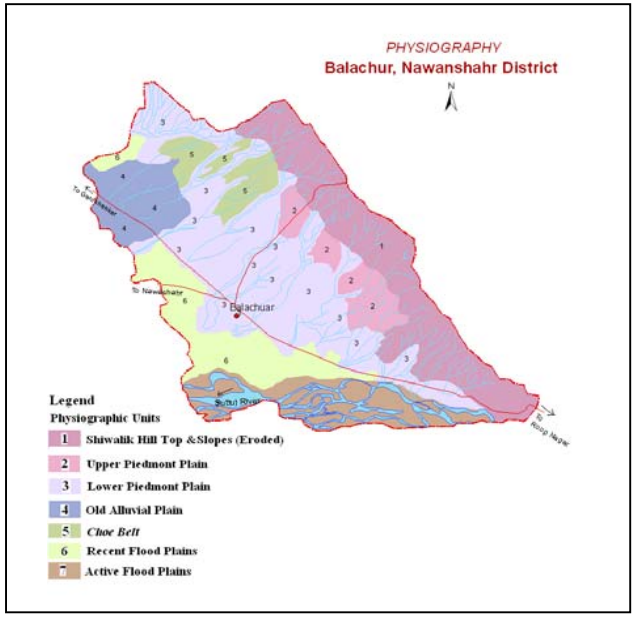

Figure 2 Physiography map, Balachur Tahsil

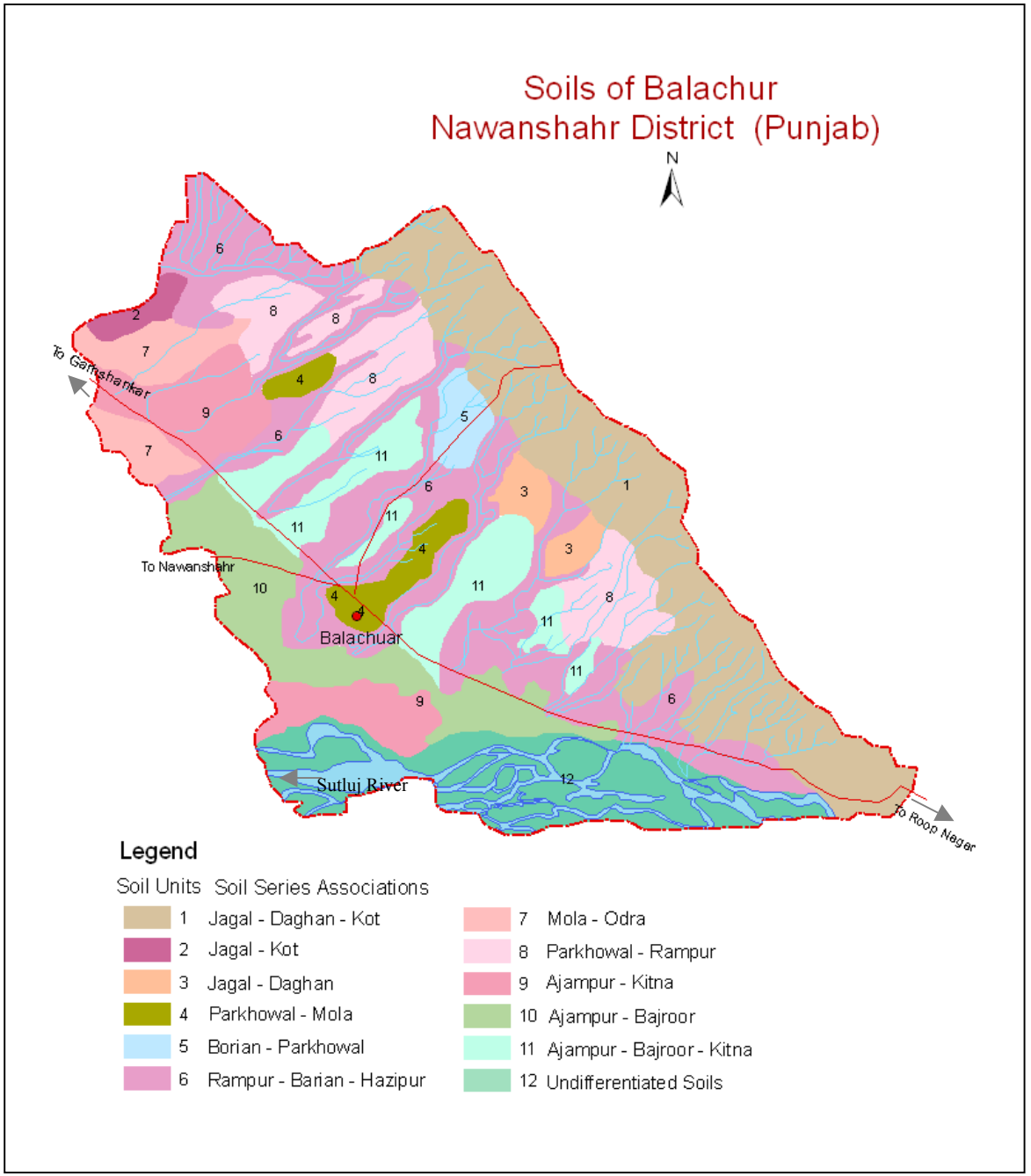

Figure 3 Soil Map of Balachur Tahsil, Nawanshahr District, Punjab

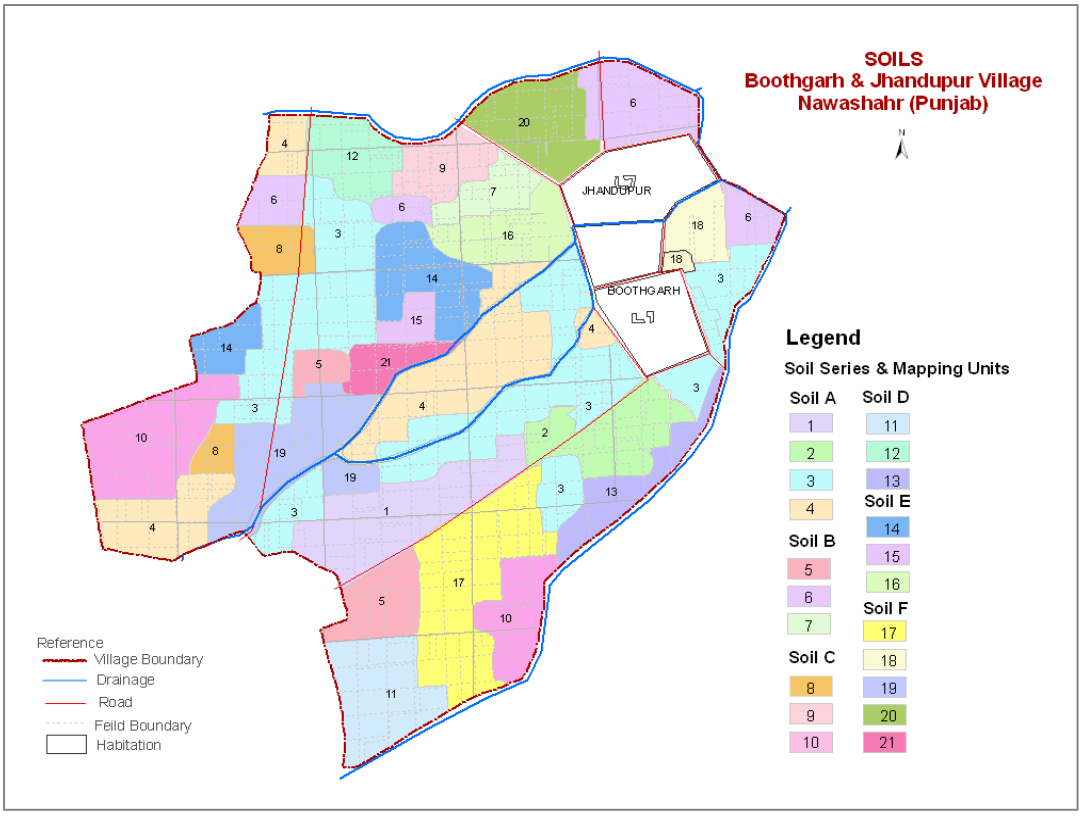

Figure 4 Soil Map of Boothgarh and Jhandupur Village, Balachur, Nawanshahar district

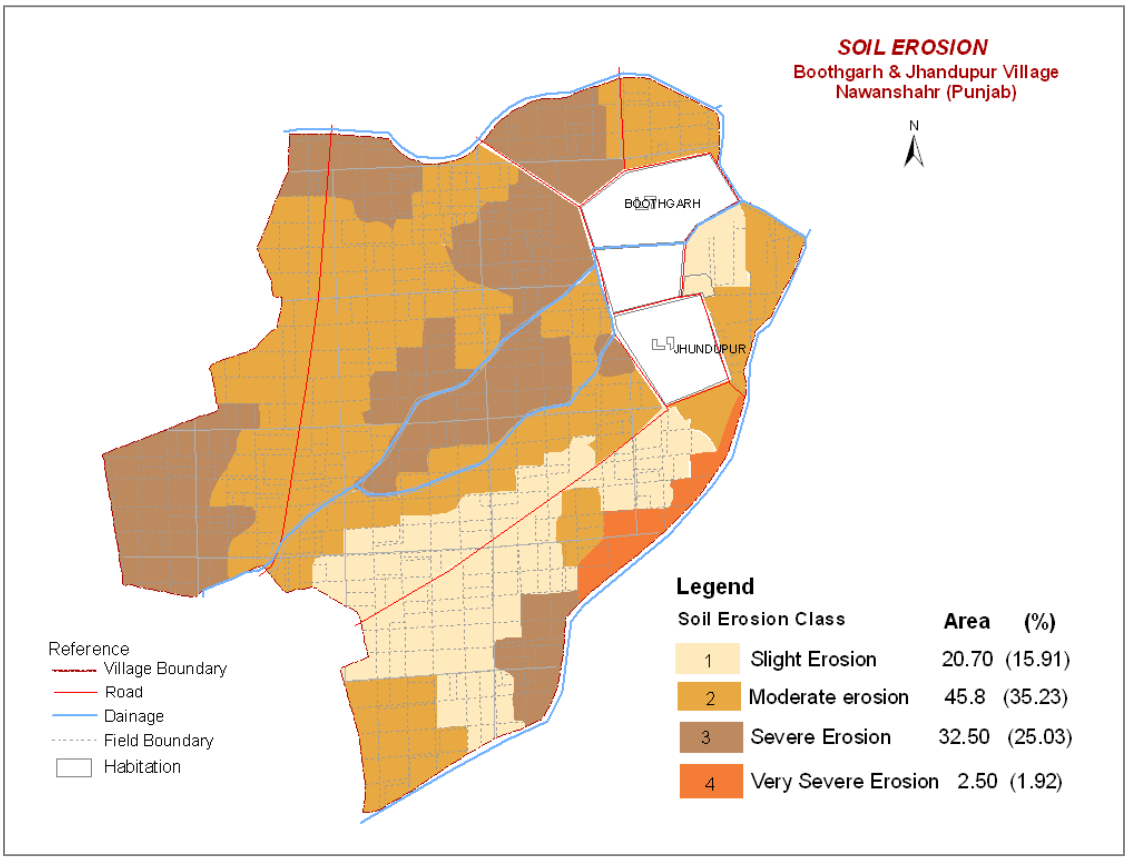

Figure 5 Soil erosion map of Boothgarh & Jhandupur, Balachur, Nawanshahar, Punjab